BOOK REVIEW

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Michael I. Mishchenko, Larry D. Travis, Andrew A. Lacis: *Scattering, Absorption, and Emission of Light by Small Particles*; 2002, XV + 445 p., 168 figures; hard-cover GBP 65.00; Cambridge University Press, Cambridge, United Kingdom, ISBN 0-521-78252-X.

This excellent book is bound to become the principal standard reference on scattering of electromagnetic radiation by small particles. It is not a university-course textbook but a thorough and up-to-date review of both theory and solution techniques. The theory starts with the Maxwell equations; the solution techniques include detailed computer code descriptions. The presentation is impeccable, with good illustrations, complete references (including useful "further reading" sections at the end of each chapter), thorough appendices, and a useful symbol specification list. The book is a must for researchers in planetary atmosphere, climate, and remote sensing research. It is likely to also find many readers in varied other technology and science endeavours.

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BOOK REVIEW

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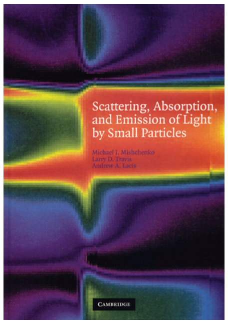
SCATTERING, ABSORPTION, AND EMISSION OF LIGHT BY SMALL PARTICLES

Michael I. Mishchenko, Larry D. Travis, and Andrew A. Lacis, 2002, 445 pp., $90.00, hardbound, Cambridge University Press, ISBN 0-521-78252-X

Electromagnetic wave scattering by small particles is an interdisciplinary area of research with applications to fields ranging from biomedicine to climate research and remote sensing. The particles encountered in nature often deviate from the spherical and homogeneous model of the well-known Lorenz-Mie scattering theory. Recent technological advancements in observing systems, measuring techniques, and computers have enhanced our ability to observe and simulate physical systems. Along with the new applications, the need for accurate calculations of scattering, absorption, and emission properties of a wide range of irregular shapes and heterogeneous composition particles is prominent.

Mishchenko's book fills the need for an up-to-date and comprehensive description of theory, numerical methods, and practical applications on light scattering absorption and emission by small particles. The author does an excellent job of combining all the material into a coherent story. The book has the potential to serve as a reference book for researchers in a wide range of fields. The material is better organized than in previous works (e.g., Mishchenko et al. 2000), and provides an effective explanation of how the scattering and absorption properties behave in a much more general context than that provided by the Rayleigh theory (traditionally the realm of radar meteorologists). It puts universally accepted truths such as, “an oriented oblate spheroid produces positive ZDR because the horizontal axis is greater than the vertical one,” into perspective, and thus, can effectively lead to new areas of applications.



The book is divided into three parts: I–Basic Theory; II–Overview of Methodologies; and III–Results (mainly simulations). Part I deals with the “basic theory of electromagnetic scattering, absorption, and emission.” All necessary quantities (such as the Stokes parameters, scattering matrix, phase matrix, etc.) are introduced, and all the important relations (such as far-field scattering, reciprocity, etc.) are derived. The presentation is concise, clear, and self-contained. Unavoidably, there is overlapping with other books in the field. In particular, the choice of material follows closely that of Mishchenko et al. (2000) – for example, in chapter 1. In his previous work, however, the emphasis is on simply presenting the results, without giving details of the derivations, whereas here Mishchenko provides a more expanded and thorough presentation. Furthermore, much of the material has also been covered by Bohren and Huffman (1983) and van de Hulst (1957). Since these earlier treatments contained many new derivations and insights, they were more original than the present book. Nevertheless, this first section of the book is useful, mainly because it is well organized and because it describes accurately the present state-of-the-art in theoretical studies of electromagnetic wave scattering by nonspherical particles.

Part II deals with the “calculation and measurement of scattering and absorption characteristics of small particles.” Most of it is devoted to the T-matrix method; the Lorenz-Mie theory is derived as a particular case of the T-matrix formulation. The material is an extended version of Mishchenko et al. (2000). Here, the derivations are described in greater detail and the presentation is much more self-contained. In particular, the following material has been added: 1) the procedure for computing the elements of the T-matrix is presented [following Tsang et al. (1985)]. 2) Mishchenko’s T-matrix computer codes, which are also used by the meteorological community, are described in detail, including instructions on how to use them as well as illustrative examples. Other techniques using exact, approximate, and experimental methods, respectively, are discussed.

Part III presents many results (mainly from T-matrix simulations) for the scattering and absorption properties of a variety of particles. The authors devote one full chapter to spheres, which they use as exemplar small particles. The properties of particles of other shapes are then discussed relative to those of equal-surface spheres. The main question addressed is, how are deviations in the shape of a particle (with respect to a sphere) manifested in its scattering and absorption properties? Relative to previous treatments, the material on spheres overlaps partly with that of Bohren and Huffman (1983), whereas the material for nonspherical particles is, to a great extent, not available in other books. Overall, the chapter on nonspherical particles is the most important contribution of the book. The authors give reference results for a wide range of particle shapes (spheres, spheroids, finite cylinders, Chebyshev particles, polyhedral particles, irregular particles, clusters of spheres, spheres with inclusions), several size parameters (from Rayleigh to geometric optics regime), and a number of scattering parameters (cross sections, angular scattering patterns, etc.). The presentation is clear and logically organized. First, results for monodisperse spheres are given. Next, the effects of averaging over size are discussed. Then, the effects of nonsphericity and of averaging over orientations are considered. Finally, the effects of averaging over shape are addressed. This final process is shown to transform the feature-full (e.g., rainbows, glories, etc.) angular scattering patterns of spheres to the featureless angular scattering patterns that are typically observed experimentally for naturally occurring collections of particles.

Mishchenko's book has a place in the related literature as a standard reference on light scattering by small particles. It may be a rather narrow story, but it is a full one. Theoreticians in particular will enjoy having the theoretical material (including the derivations), the information on computer codes, and the detailed numerical studies in the same volume. The book contains good illustrations and a plethora of detailed and complete references, including interesting "further reading" sections at the end of each chapter.

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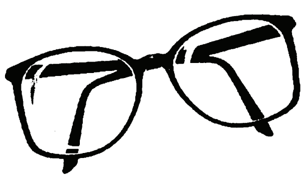
Scattering, Absorption, and Emission of Light by Small Particles

by Michael I. Mishchenko, Larry D. Travis and Andrew A. Lacis

Cambridge University Press, 2002, 445 pp, US$90.00
ISBN 0-521-78252-X

Book reviewed by Syd Peel[1]

Electromagnetic scattering figures prominently in meteorology, climatology and oceanography. Radar loops of thunderstorms and synoptic-scale precipitation fields are crucial to timely, accurate weather forecasts and warnings. Satellite-based instruments, sampling a wide range of the electromagnetic spectrum, not only permit the observation of weather patterns on a larger scale than can be observed in radar imagery, but also monitor a diverse assortment of environmental fields, from the temperature of the ocean surface to the thickness of the stratospheric ozone layer. Satellite-based radars map the extent and thickness of sea ice, provide global-scale rainfall estimates, and measure winds and waves over the oceans.



A firm grasp of the theory of electromagnetic scattering is important not only for the correct interpretation of the output generated by the myriad instruments which remotely monitor the state of the environment. Weather is simply a manifestation of the mechanical work done by the tropospheric heat engine, and the energy fuelling this engine derives from the solar radiation absorbed by the earth and its atmosphere.

In their book *Scattering, Absorption, and Emission of Light by Small Particles*, Mischenko, Travis, and Lacis survey the current state of the field, with a particular emphasis on numerical solutions. The book is comprised of three parts, beginning with the theoretical underpinnings for the subject, proceeding to the computational aspects of the problem, and finally sampling some results of the application of the theory and numerical methods developed earlier in the book.

The first part of the book focusses on the scattering and phase matrices which describe the attenuation and change in polarization experienced by the beam upon scattering. These matrices are examined in considerable detail, particularly their transformation properties and simplifications which obtain when the scattering system possesses certain symmetries. These simplifications can dramatically improve computational performance when attempting to solve complex scattering problems which closely approximate real-world conditions. The radiative transfer equation is also introduced and explained, including the limits of its applicability.

The lion's share of the discussion in the second part of the book on computational methods is devoted to the T-matrix technique. The incident and scattered electromagnetic fields are projected onto a basis of vector spherical wave functions, their radial dependence given by spherical Bessel functions and their angular dependence by associated Legendre functions. The T (transition) -matrix relates the coefficients of the expansion of the scattered beam in this basis to the coefficients of the incident beam in the same basis. Properties of the T-matrix are derived which can greatly simplify its computation, and the steps to follow in the application of the T-matrix method to the solution of a scattering problem are explicitly prescribed. The chapter concludes with a discussion of computer programs implementing the Lorenz-Mie and T-matrix methods, including detailed descriptions of the parameters input to, and the output produced by, the software considered, illustrated with applications to a variety of scattering configurations.

Other differential- and integral-equation techniques for the solution of scattering problems, such as separation of variables, finite-element, and finite-difference methods are also mentioned. However, as the authors freely admit, considerably less attention is paid to these approaches than was devoted to the T-matrix and Lorenz-Mie techniques. The penultimate chapter in this part of the book is devoted to some common approximations invoked to simplify the scattering problem, including the Rayleigh, Rayleigh-Gans (or Born) and geometrical optics approximations.

The middle part of the book culminates in a brief chapter on experimental electromagnetic scattering. The authors contrast the physical characteristics intrinsic to experiments conducted at the visible and infrared versus the microwave segments of the spectrum, outline the practical and theoretical ramifications for the experimenter, and summarize experimental work to date.

The third part of the book surveys the current state of knowledge of the scattering and absorption of radiation. Homogeneous spheres are considered first since their symmetry affords analytic solution by the Lorentz-Mie theory, and many scattering systems can be approximated reasonably well by such spheres. In the final chapter the T-matrix technique is brought to bear on more complicated scattering configurations which arise in a wide array of real-world situations. These applications are by far the most interesting part of the book. While the discussions are tantalizingly brief, the voluminous references to the literature permit the interested reader to explore in greater depth those problems pertinent to their own particular interests.

This book is very well written, delivering a vivid presentation of the subject, assisted in this regard by an abundance of clear, often colourful, illustrations. Derivation of the equations is generally quite lucid, often explicit, facilitated by meticulous attention to a clear, consistent notation. While focussing on computational approaches to the problem, the underlying physical principles are never neglected. Indeed,

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the powerful numerical techniques examined in the book are exploited to elucidate scattering phenomena in such highly complicated configurations as arise, for example, in applications to the remote sensing of the atmosphere.

While certainly an invaluable reference for the practitioner in the field, this is hardly the book to initiate the neophyte. In principle, the exposition is largely self-contained, predicated upon a familiarity with Maxwell's equations, which are the launching point for the book. In practice, mastery of electrodynamics at the level of a text such as J.D. Jackson's classic in the field, particularly the use of Green's function techniques and the dyadic representation of second-rank tensors, would ease the assimilation of the material. Clebsch-Gordan coefficients and Wigner 3j symbols are employed liberally in the development of the Lorenz-Mie theory and the T-matrix method - while there is an appendix devoted to them there is little in the way of orientation or motivation, and some previous exposure to these techniques would be helpful.

The newcomer to the field should first consult an introductory text such as Liou's *An Introduction to Atmospheric Radiation*. If this serves only to whet their appetite for further investigation into the subject, then they'd certainly profit from the book of Mischenko et al. The book contains a reference to the web page http://www.giss.nasa.gov/~crmim, hosted at the NASA Goddard Institute for Space Studies. Code for the solutions of scattering problems, in particular those implementing the Lorenz-Mie and T-matrix methods, can be found at this site, as well as an electronic version of their book. With this software, and the book to guide in its application, readers can conduct their own scattering experiments - certainly the best way to master the field and ultimately make their own contribution to a fertile science with far-reaching application to meteorology and oceanography.
